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ISOTOPE SEPARATING APPARATUS CONTROL

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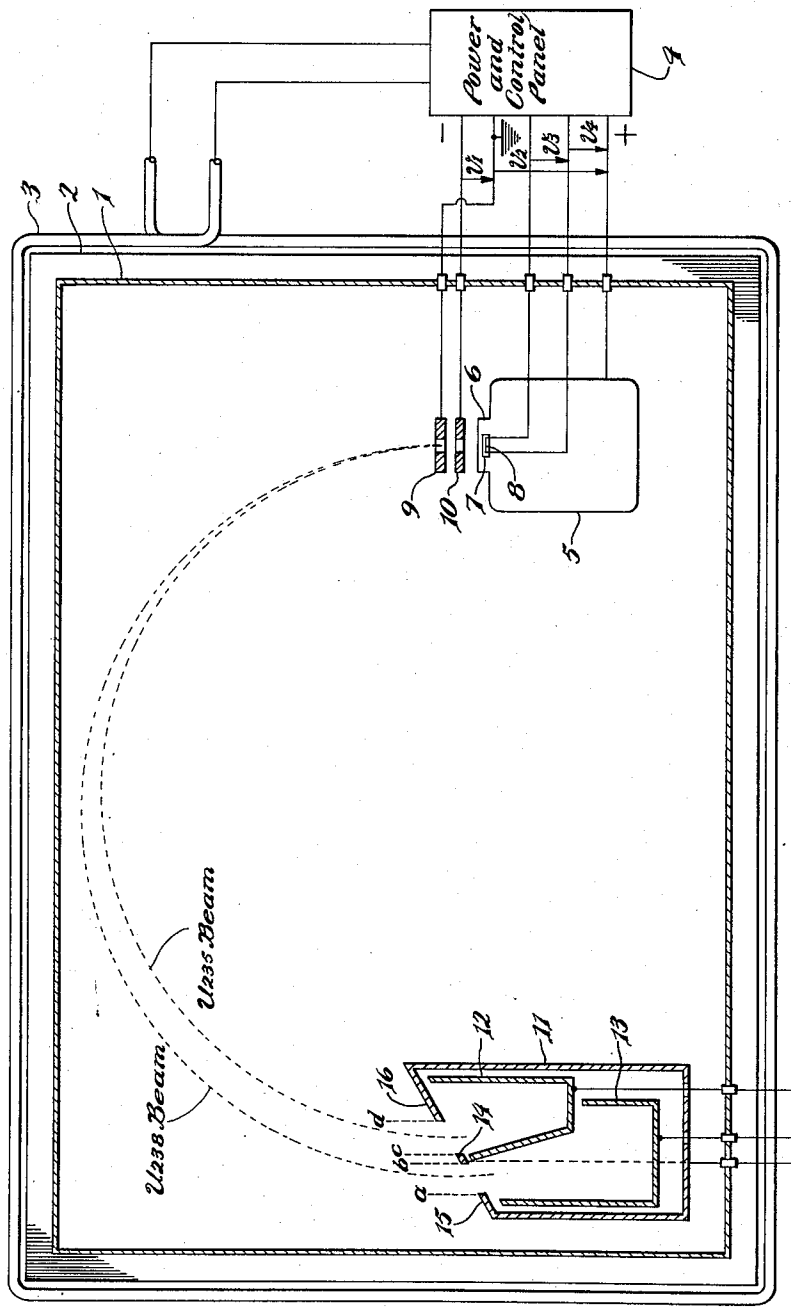


FIG. 1.

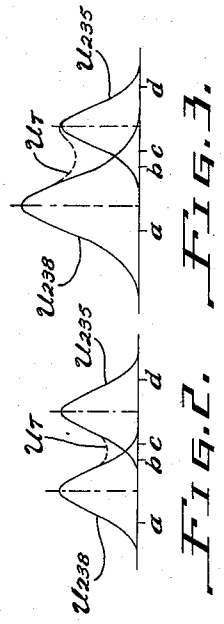


FIG. 2.

INVENTOR.
Sidney W. Barnes
BY
Robert A. Lavender
Attorney

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ISOTOPE SEPARATING APPARATUS CONTROL

Sidney W. Barnes, Rochester, N.Y., assignor, by mesne assignments, to the United States of America as represented by the United States Atomic Energy Commission

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6 Claims. (Cl. 250—41.9)

This invention relates generally to isotope separating apparatus of the electromagnetic type, commonly referred to as a calutron, and is more particularly concerned with improvements in methods of and means for controlling the position and condition of the ion beam of such calutrons for optimum operation.

While the apparatus of the present invention is not limited to the separation of the isotopes of any one element, it must of necessity be specially adapted for the masses involved, and in order for its principles to be clearly understood, the invention will be described as embodied in apparatus adapted for the separation of the uranium isotopes having atomic weights 235 and 238, the isotope having an atomic weight of 234 being ignored.

In such calutrons, a beam of positive ions of uranium is formed and projected at a high uniform velocity into an evacuated region traversed by a substantially uniform magnetic field at right angles to the direction of motion of the ions. As a result, each particular ion is caused to describe a circular path having a radius proportional to the square root of its mass. In this way the original single ion beam is split into two more or less distinct component beams, one of which consists of uranium ions having a mass of 238 and the other of which consists of uranium ions having a mass of 235. Because of a geometrical focusing action, these two beams are most distinctly resolved after the completion of 180° of their circular path, and the U_{235} and U_{238} ions may be separately collected at a receiver located at this point.

An important consideration in the optimum operation of such calutrons is the ion beam control or monitoring problem, which in turn may be divided into two separate problems. First, the ion beam as a whole must be positioned with respect to the receiver such that the U_{235} and U_{238} beams fall correctly into their respective receiver pockets. Secondly, the individual beams must be focused on sharpened to as great an extent as possible, that is, the resolution of the beams must be good at the receiver. The control to attain both these conditions must be effected continuously while the calutron is in operation.

One prior method of controlling the ion beam such as to provide optimum operation was first to adjust the variables controlling the position of the whole ion beam with respect to the receiver so as to provide a maximum reading on the meter connected to the U_{238} collecting pocket, and that having been done, to then adjust the variables controlling the focusing or resolution of the beams such that the ratio of the U_{238} meter reading to that of the U_{235} meter reading was a maximum.

The above-described method of control, and other prior methods, however, are all particularly adapted to the case where the U_{235} ion beam is small compared to the U_{238} ion beam, that is, where the relative proportions of U_{235} and U_{238} atoms in the charge material are substantially the same as those occurring in nature. A different control problem is presented in the case where the charge material has already been enriched with respect to U_{235} atoms, and it has been found that prior methods

of control are not satisfactory under these circumstances. By the present invention, the inventor has provided a simple, efficient, and accurate control system for a calutron operating with uranium charge material which has been previously enriched with respect to U_{235} atoms. This control system is particularly applicable to the separation of two adjacent isotopes of any material wherein the relative proportions of the two isotopes are of the same order of magnitude. As a result of previous isotope enrichment processes, any two adjacent isotopes of any material may have arrived at a state of substantially equal relative proportions, as described above with respect to the U_{235} and U_{238} isotopes. Also, certain adjacent isotopes of certain materials occur naturally in substantially equal relative proportions. Examples of such isotopes are: Mg_{25} (11.5%) and Mg_{26} (11.1%); Ti_{46} (7.95%) and Ti_{47} (7.75%); Ti_{49} (5.51%) and Ti_{50} (5.34%); Kr_{82} (11.53%) and Kr_{83} (11.53%); Mo_{95} (16.3%) and Mo_{96} (16.8%); Pd_{106} (27.2%) and Pd_{108} (26.8%); Ag_{107} (52.5%) and Ag_{109} (47.5%); Cd_{110} (12.8%) and Cd_{111} (13.0%); Sn_{122} (5.5%) and Sn_{124} (6.8%); Sb_{121} (56%) and Sb_{123} (44%); Sm_{147} (17%), Sm_{148} (14%) and Sm_{149} (15%); Eu_{151} (49.1%) and Eu_{153} (50.9%); Dy_{162} (24.6%) and Dy_{163} (24.6%); W_{184} (30.1%) and W_{186} (29.8%); Os_{186} (1.59%) and Os_{187} (1.64%); and Pd_{206} (23.59%) and Pd_{207} (22.64%).

In accordance with the principles of the present invention, the calutron receiver or collector is provided with an additional insulated electrode positioned intermediate the usual U_{235} collecting pocket and the U_{238} collecting pocket. As will later be described in detail, the deionizing current which flows from ground to this additional electrode is a minimum when the ion beams are properly positioned and focused. The method of control, then, comprises the steps of adjusting the variables controlling the position of the beams with respect to the receiver, and also the variables controlling the focus of the beams, so as to minimize this deionizing current to the additional electrode.

Accordingly, it is the primary object of the present invention to provide a method of and means for controlling a calutron ion beam for optimum operation.

Another object of the invention is to provide a novel calutron receiver particularly adapted to provide an ion beam current indication useful in determining the attainment of optimum operating conditions for the calutron.

Still another object of the invention is to provide a novel calutron receiver having, in addition to the usual insulated pockets for collecting the component isotope ion beams, an electrically independent electrode intermediate said pockets.

A further object of the invention is to provide a novel calutron receiver having, in addition to the usual insulated pockets for collecting two individual isotope ion beams, an insulated electrode positioned to receive the inner adjacent fringes of said beams.

Still a further object of the invention is to provide a method of ion beam control wherein the variables controlling the position of the ion beam are first adjusted until a minimum ion current is received at a region intermediate the component isotope ion beam collecting pockets, and then the variables controlling the focus of the ion beam are adjusted until a new minimum ion current is received at this region.

Another object of the invention is to provide a method of ion beam control wherein the ion current received at a region intermediate the individual isotope ion beam collecting pockets is minimized by suitably controlling the position and focus of the beam.

Other objects and advantages will become apparent from the specification taken in connection with the ac-

companying drawings wherein one embodiment of the invention is illustrated.

In the drawings, Fig. 1 is a diagrammatic sectional view of a calutron showing the new type receiver with its additional electrode.

Fig. 2 and Fig. 3 illustrate typical beam intensity patterns for the U_{235} and U_{238} beams across the face of the receiver useful in explaining the principles of the invention.

Referring now to Fig. 1, reference numeral 1 represents an evacuated vessel or tank which it will be understood is transversed by a substantially uniform magnetic field at right angles to the paper and produced by an electromagnet, one pole piece 2 of which is shown. The magnetizing winding 3 of this magnet is supplied with magnetizing current from a power and control panel 4. It will be understood that suitable apparatus is included in the control panel 4 for regulating and adjusting the magnetizing current flowing through winding 3.

Reference numeral 5 indicates a source of positive uranium ions which may be of a type more completely described in U.S. patent application Ser. No. 561,271, entitled "Temperature Control" and filed October 31, 1944, in the name of Emmett V. Martin, now Patent No. 2,712,073, dated June 28, 1955. As described in that application, there is included within the ion source 5 a container of charge material and suitable heating means associated with the container for vaporizing the uranium compound contained therein. The uranium vapor is then channeled through a passageway to the elongated constricted top portion of the ion source 5 which portion forms an ionization chamber 6.

A slot 7 is formed in one end of the ionization chamber 6 and adjacent to this slot and aligned therewith is a filament 8. Filament 8 is connected to a filament supply voltage V3 at the power and control panel 4. One side of filament 8 is maintained at a negative potential V4 with respect to the source unit 5 so that the source unit becomes an anode for the filament. As a result an electric arc is maintained from the filament 8 through the slot 7 and lengthwise along the interior of the ionization chamber 6. This arc serves to disassociate and ionize the uranium compound vapor in the ionization chamber 6, and the resulting uranium ions are then withdrawn by an accelerating system through an elongated slot, not shown, in the top of the ionization chamber 6.

The voltage supply V4, which will henceforth be referred to as the ionization arc voltage, is one variable which controls the focusing of the ion beams. This ionization arc voltage is always maintained sufficiently high so that the filament 8 operates at maximum emission. Accordingly, by varying the filament supply voltage V3, the ionization arc current, which is another factor influencing the beam focus, may be controlled.

The accelerating system comprises a slotted electrode 9 maintained at a high negative potential V2 with respect to the ion source 5, and a second slotted electrode 10 maintained at a high negative potential V1 with respect to the accelerating electrode 9. In operation the positive uranium ions in the ionization chamber 6 are first accelerated by electrode 10, and then decelerated somewhat by electrode 9 to a final constant velocity at which they traverse the tank in a circular path to the receiver indicated generally at 11. Since the final velocity of the ions is determined by the potential V2 of electrode 9 with respect to the source unit 5, this potential V2 will be referred to as the accelerating potential, and the electrode 9 will be referred to as the accelerating electrode. Since the potential V1 of the electrode 10 with respect to electrode 9 does not in any way effect the final velocity of the ions, but rather primarily effects the resolution or focusing of the resulting beams, this potential V1 will be referred to as the focusing potential and the electrode 10 will be referred to as the focusing electrode.

All of the voltage supplies V1, V2, V3, and V4 may be, and preferably are, regulated and adjustable at the power and control panel 4. Although the ground connection may be placed at any point in the potential system, it is found to be more convenient in most cases to connect the accelerating electrode 9 and the receiver 11 to ground, as shown. The polarities of the voltages are from minus to plus in the direction of the arrows.

It will be apparent from the foregoing that the position of the ion beams with respect to the receiver may be varied by adjusting the accelerating potential V2, or by adjusting the magnetizing current which flows through the magnetizing winding 3. The shape of the beam intensity patterns, that is, the focusing of the ion beams, may be controlled by suitable adjustments of the focusing potential V1, the ionization arc potenital V4, and the ionization arc current, which latter is controlled by varying the filament supply voltage V3 to thereby vary the emission of the filament 8.

As has been previously stated, the single ion beam emerging from the accelerating electrode 9 is constrained to flow in a circular path, and since the radius of the circular path taken by any individual ion is proportional to the square root of the mass of that particular ion, two more or less distinct ion beams are formed, the one of smaller radius (U_{235} beam) consisting of U_{235} ions, and the other of a larger radius (U_{238} beam) consisting of U_{238} ions.

The receiver 11 comprises two insulated pockets 12 and 13 for receiving the U_{235} and U_{238} beams, respectively. An additional insulated electrode 14 is positioned intermediate the entrance slot *c—d* to the U_{235} pocket 12 and the entrance slot *a—b* to the U_{238} pocket 13 so as to receive that portion of the whole ion beam which arrives at the receiver in the region *b—c*. Entrance slot *c—d* to the U_{235} pocket 12 as defined by face plate 16 and the inner end of electrode 14, whereas entrance slot *a—b* to the U_{238} pocket 13 is defined by the outer end of electrode 14 and a second face plate 15. Pockets 12 and 13 and electrode 14 are connected to ground through ammeters 16, 17 and 18, respectively, which ammeters thereby provide a visual indication of the respective deionizing currents to the operator at the power and control panel 4.

The detailed design of the receiver, which forms no part of the present invention may be in accordance with conventional practice. Pockets 12 and 13 and electrode 14 are suitably supported in the receiver and are insulated from each other, and are preferably made of carbon to impart durability. Although in the drawings, it is indicated that the electrode 14 is supported at the ends, this electrode could be made integral with the outer wall of pocket 12 as a conducting insulated tip thereof.

Referring now to Fig. 2, wherein a typical ion beam intensity pattern is shown in its desired position with respect to the receiver, the U_{235} component pattern, and the U_{238} component pattern are indicated separately in solid lines. The total beam intensity pattern U_T, which is, of course, the sum of the separate U_{235} and U_{238} components, is identical with the individual patterns over the region where these do not overlap, and is indicated as a dotted line in the region where overlapping occurs.

Since the U_{235} and U_{238} patterns are equal in Fig. 2, this figure represents the case where enriched charge material containing equal numbers of U_{235} and U_{238} atoms is used. In this case it is usually desirable to have the maximum or peak of the component beam intensity patterns positioned over the center of the entrance slots to their respective collector pockets, as shown. It will be apparent that when this condition is attained the number of ions arriving at the receiver in the region

b—*c*, which is the integral under the wave U_T from *b* to *c*, will be a minimum. Moreover, if the focus of the beam is improved as much as possible so that the component patterns are made very sharp and very narrow, the current to electrode **14** is further minimized.

In operation, the accelerating voltage **V2** is first adjusted until the ion beam assumes its desired position with respect to receiver **11**, the attainment of this condition being evidenced to the operator by a minimum reading on the ammeter **18** which records the deionizing current to electrode **14**. This adjustment of the position of the beam with respect to the receiver could as well be accomplished, but rather less conveniently, by suitably varying the magnetizing current of winding **3** and thereby the intensity of the magnetic field. The correct positioning of the beam having been accomplished, the various factors which control the focus of the beam, namely, voltage supplies **V1**, **V3**, and **V4**, but notably the focusing potential **V1**, are then adjusted so as to sharpen the component beams to as great an extent as possible, the attainment of this condition being evidenced by a further minimizing of the reading of ammeter **18**. After these initial adjustments have been made, it may be advantageous to repeat the entire procedure several times until the optimum operating condition is attained both with respect to the position of the beam and the focusing thereof.

In Fig. 3, a typical beam intensity pattern is illustrated for the case where the charge material employed contains perhaps twice as many U_{238} atoms as U_{235} atoms. In this case, it can be seen that the trough in the U_T pattern is no longer exactly centered between the peaks of the component patterns, but rather is shifted toward the pattern of the less abundant beam. Now when the beam is positioned so as to minimize the current to electrode **14** in accordance with the above-described operating procedure, the pattern will assume a position with respect to the receiver as indicated in Fig. 3. It will be noted that in this position the peaks of the component beams are no longer exactly centered over the entrance slots *a*—*b* and *c*—*d*, but rather are shifted slightly in the direction of the U_{238} pocket.

This shift, however, is very slight and may even be desirable depending on the purpose of the particular run. If, for instance, the degree of enrichment rather than the quantity of material collected in the U_{235} pocket is the primary consideration, this shift will be advantageous.. This is true because by offsetting the peak of the U_{235} pattern to the left from the center of the entrance slot *a*—*b*, more U_{238} ions have been lost to pocket **12** than U_{235} ions, and although less actual material will be collected in the U_{235} pocket, nevertheless, the percentage of U_{235} therein will be greater.

On the other hand, if the most efficient collection of U_{235} and U_{238} ions in the pockets were the prime consideration, the shift would be undesirable. In such case, the amount of shift could be predetermined for the isotope ratio of the particular charge material to be used, and the shift could be avoided by a proper design of the receiver. As shown in the drawings, the entrance slots *a*—*b* and *c*—*d* are indicated to be equal and the electrode **14** positioned exactly intermediate their centers. It will be apparent that for the isotope ratio represented in Fig. 3, it would be possible to design a receiver having entrance slot *a*—*b* larger than *c*—*d*, so that when the beam is positioned on the receiver so as to minimize the current to electrode **14** in accordance with the operating procedure outlined above, the peaks of the component beams would still fall at the center of their respective entrance slots. By proper design of the receiver **11** therefore, it is possible to compromise between efficiency of collection on one hand and enrichment

of the material collected in the U_{235} pocket in any manner desired.

Since many changes in the above construction, and many apparently widely different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. The method of controlling a calutron ion beam for optimum collection of two adjacent component beams thereof at respective collecting pockets of a receiver, comprising the steps of adjusting the position of said beam with respect to said receiver until a minimum ion current is received at an electrode disposed in said receiver intermediate said pockets, and varying the focus of said beam until a further minimum ion current is received at said electrode.

2. The method of controlling a calutron ion beam for optimum collection of two adjacent component beams thereof at respective collecting pockets of a receiver, comprising the steps of adjusting the variables controlling the position of said beam with respect to said receiver until a minimum ion current is received at an electrode disposed in said receiver intermediate said pockets, and adjusting the variables controlling the focus of said beam until a further minimum ion current is received at said electrode.

3. The method of controlling a calutron ion beam for optimum collection of two adjacent component beams thereof at respective collecting pockets of a receiver, comprising the steps of adjusting the accelerating potential until a minimum ion current is received at an electrode disposed in said receiver intermediate said pockets, and adjusting the focusing potential until a further minimum ion current is received at said electrode.

4. The method of controlling a calutron ion beam for optimum collection of two adjacent component beams thereof at respective collecting pockets of a receiver, comprising the steps of adjusting the accelerating potential until a minimum ion current is received at an electrode disposed in said receiver intermediate said pockets, and adjusting the focusing potential, and the ionization arc potential and current until a further minimum current is received at said electrode.

5. A calutron receiver comprising means forming a first insulated pocket disposed in said receiver for receiving and collecting a first ion beam composed of ions of a particular mass, means forming a second insulated pocket disposed adjacent to said first pocket for receiving and collecting a second adjacent ion beam composed of ions of a different mass, an insulated electrode disposed intermediate said pockets for receiving the inner adjacent fringes of both of said component ion beams, and meter means connected to said insulated electrode for indicating the deionizing current to said electrode.

6. A calutron receiver comprising means forming a first insulated pocket disposed in said receiver for receiving and collecting a first ion beam composed of ions of a particular mass, means forming a second insulated pocket disposed adjacent to said first pocket for receiving and collecting a second adjacent ion beam composed of ions of a different mass, an insulated electrode disposed intermediate said two pockets for receiving the inner adjacent fringes of both of said component ion beams, and respective meter means connected to said pocket forming means and said electrode, respectively, for indicating the respective deionizing currents to said pockets and said electrode.

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